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Improving projects evaluations in analyzing transport models ability to explain the past

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Abstract

GLOBAL, the RATP transportation model, was recently updated to its 9th version. This was the opportunity to reconsider its methodology, and, more generally, the relevance of four-stage models for medium-to-long term planning studies. Indeed, a model's validity is generally assessed through its ability to replicate traffic counts. Considering that a good replication of the present leads to an accurate forecast of the future is an important assumption. It mainly implies a hypothesis of stability of mobility behavior, which could be questionable, and even more when many parameters are used, as it is the case for a large and complex network. The issue was addressed by carrying out the exercise in reverse, that is to say by analyzing the model's ability to explain the past. GLOBAL 9th version, estimated using the 2010/2011 Parisian household travel survey has been applied on all the past household survey years (1976, 1983, 1991 and 2001). This way, estimates could be compared with survey results in terms of demand volumes, mode shares and also with past public transport counts on main railway lines.
The analysis of the discrepancies between the estimates and survey results clearly shows the limits of the mobility behavior stability hypothesis. Indeed, this assumption gives the model a high inertia, which is important to keep in mind when examining and interpreting modelling results. However, the discrepancies of predicted demand flows versus observed ones stay within an acceptable range. The exercise was then a good illustration of the uncertainties associated with the modeling results.

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Keywords: Backasting; four-step model; model validation; traffic forecasts; traffic modeling; household survey

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1. Introduction

In the 1970s, RATP began the internal development of GLOBAL, its transportation model (Labbe & Scherrer, 1975; RATP, 2013-2014). It is an aggregate 4-stage multimodal model. Since then, while the public transportation network was evolving, the model has been greatly improved and new features have been added. It has been used in many projects of urban railways, subway extensions and recently for trams.

However, the development of a model involves finding a balance between its complexity and its ease of use and interpretation. Indeed, it is very important to keep it understandable to the users. In order to guaranty the model relative simplicity, some simplifications in algorithms have been made. For instance, one of the main simplifications is probably the stability hypothesis of mobility behavior over time. Indeed, the model parameters are only estimated for the calibration situation, using the data of the last travel survey available, considered as the most representative of the mobility practices (Cabrera Delgado & Bonnel, 2012). Most of time, no variability is taken into account when future horizons are modelled, even though the analysis of travel surveys reveals changes in behavior over common forecasting horizons, that is to say ten to twenty years. This stability assumption could thus be questionable, and even more when many parameters are used, as it is the case for a large and complex network like the Parisian one. The consequences of these simplifications on modelling results are still poorly understood. Yet it seems important to keep them in mind, especially as traffic forecasts help evaluate the effect of a new policy or estimate the size of the future infrastructure over (very) long-term horizons.

In this context, GLOBAL update to its 9th version was an opportunity for us to reconsider the methodology of our model, and, more generally, the relevance of four-stage models for medium-to-long term planning studies. In this paper, it is proposed to address this issue by carrying out the exercise in reverse, that is to say by analyzing our transport model ability to explain the past. GLOBAL, which 9th version has recently been estimated using the 2010/2011 Parisian household travel survey (Enquête Globale Transport – EGT), has been applied on all the past household survey years (1976, 1983, 1991 and 2001). This way, estimates could be compared with survey results in terms of volumes, mode shares and also with past public transport counts on main railway lines.

2. The back-casting analysis

A back-casting analysis consists in testing a model's capability to correctly predict observed changes in the demand pattern. In Ile de France, the six household travel surveys allow monitoring the evolution of mobility practices in the region. They display several changes in behavior, making appropriate this exercise. Thus, the volume of trips during morning peak hours significantly increased between 1976 and 2010 (about +1% per year). This evolution has been accompanied with both changes in the geographic distribution of the trips (the weight of suburbs-to-suburbs trips has been risen since 1976) and, more recently, a trend break regarding modal share. Indeed, 2001 marked the end of the increase of car use in favor of public transports (Observatoire de la mobilité en Ile-de-France; Simeon, 2014)

2.1. Literature review

A backcasting analysis may follow two different approaches. The first one consists in “predicting the past” by applying the model to a horizon preceding the calibration one. This is the exercise described in the paper. The second method is to “predict the present starting from the past” applying the model, calibrated on past data, to the present year, for which observed data are also available for comparison.

Regarding the first method, we can mention that the TMIP manual on travel model validation underlines the importance of temporal validation, and considers that, to do so, backcasts can be used (Federal Highway Administration TMIP, 2010). As stated in the manual this validation is all the more important as the horizon of study is long-term, or as changes of the transport systems are important.

In addition, two examples of backcasting analysis can be named. The first one was conducted as part of the validation of the UK National Transport Model (NTM). This analysis was “judged the most valuable source of validation evidence of the general forecasting reliability (strengths and weaknesses) of the NTM” (Gunn, Miller, & Burge, 2006).The NTM was applied on two backcast periods: 1991, which corresponds two a ten-year retrospective, and 1975, a twenty-five years retrospective. These two horizons have, among others, the advantage of being usual periods for forecasts. The paper focuses on the predictions for 1991: the comparison with survey data attests of the quality of mode and destination choice results. This conclusion, however, is tempered by the authors. Indeed, few changes affecting mode and destination choice were observed over the period. Thus, the ability of the model to respond to more important mutations has not been clearly demonstrated.

The second example is the OTM model, the tactical model for greater Copenhagen, whose fifth version was validated in 2007 (Vuk & Overgaard Hansen, 2007). As part of the validation process, a backcasting experiment from 2004 (the new model base year) to 2000 was performed. This exercise was designed to test the forecasting capabilities of the model. Between 2000 and 2004, the metro was built in Copenhagen, and the public transport fares increased significantly, while the petrol price dropped. It was then interesting to analyze the response of the model to these major changes. Overall, the modeling results were satisfactory; the model correctly reflected the trends in the use of public transport. However, a more detailed analysis by mode shows some discrepancies with traffic counts. The authors found out that it was probably because of the difficulty to model route choice in cases of several alternative routes.

Examples of the second approaches can also be found in the literature. Coppola and Nuzzolo tested the forecasting capability of their activities-location choice model with a backcasting analysis: the model, calibrated on data observed at year 1981, was applied to a 2001 scenario (Coppola & Nuzzolo, 2011). They carried out the exercise with two different dwelling price models and, this way, could compare and appreciate the forecasting performances of the two methodologies.

Finally, Delgado addresses the issue of the temporal transferability of model through a backcasting exercise applied to the Lyon region (Cabrera Delgado, 2013). He shows in his thesis that such an exercise can be used to study the temporal stability of the four-stage model, provided that the comparability of surveys over time is valid.

2.2. Methodology

The calibration year of GLOBAL last version is 2010. The backasting exercise consisted in applying the model to the past household survey years: 1976, 1983, 1991 and 2001. The first step was to gather the necessary data to characterize the demand and the transport offer at these time horizons.

In order to estimate the transport demand for each group of trip purpose (work, early childhood, secondary school, high school, university and non-compulsory purposes), several data describing specific characteristics of the population and jobs were necessary at a zonal level: age groups, share of the employed population, share of the school population, share of management jobs… The data come from the population census. As it could be expected, all details were not available for each horizon, and the information was particularly hard to gather for the two earliest horizons. When there was no available data, it has been assumed that the repartition (either geographic or among the volume of population or jobs of the town) was similar to the one in the closest population census.

Past travel surveys and historical traffic counts inform about the mobility behavior and traffic levels.

As regards to the transport offer, again data was not always easy to find. Indeed, the Public Transport (PT) network in Ile de France has evolved over the past decades. Concerning the years 2001 and 1991, networks from older model version were used. They contained the description of the tramway, subway and urban railway networks. They were then imported and adapted to the current version of the model. However, the bus network was poorly described. It was therefore decided to retain the current bus network for both horizons, as it is the case for most traffic studies. Indeed, for the study of a new infrastructure, such as a subway or a tramway for instance, the bus network restructuration around the project is, usually, not known well in advance. For 1982 and 1975, the only collected information was very brief descriptions of the networks, which turned out to be greatly insufficient to be modelled. For these two years, it was decided to focus on the stages of generation and distribution (i.e. analysis of the transport demand) and not to apply the mode choice and assignment models. Finally, road networks of the past horizons could not be imported into the new version of the model. Thus, the current situation network was used.

3. Results

3.1. Generation

The comparison of the number of trips counted in the household surveys during the morning peak hours (EGT in black on Fig. 1), and the number of trips estimated by the generation model (in grey on Fig. 1) shows that the volumes of the years 1991 and 2001 are quite well recreated since the discrepancy is less than +/-10% between the two sources. The difference is bigger in 1983 (+13% of trips compared to the survey results) and in 1976 (+23%). The impoverishment of available data used to build up the past scenarios is a first explanation for the widening over time of the gap between model predictions and observed volume of trips. In addition, the volume of trips in the morning has risen faster than the regional population. Thus, if this evolution is mainly due the population growth, it also reflects an increase in individual mobility. For instance, in 1976, Paris region inhabitants used to make about 3.5 trips per day, and in 2010 this average had risen to 3.88. The model does not reproduce this change in behavior, which explains the discrepancies between model "backcast" and observed data. As it will be analyzed below, trend differs substantially between trip purpose groups and the overestimation of the volume of trips on the morning is principally explained by the overestimation of early childhood-related trips.

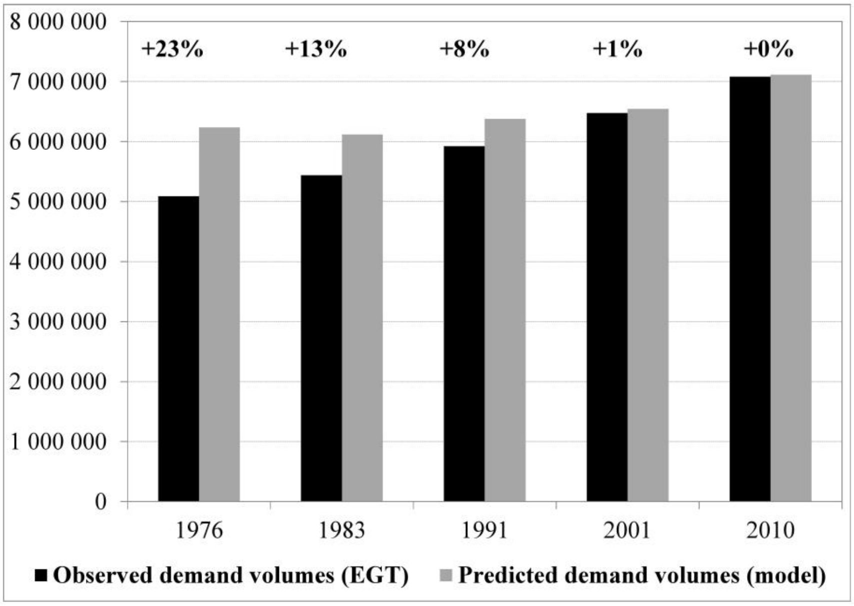

Fig. 1: Comparison of the observed volumes of trips on the morning peak hours and the predicted ones

This backcasting exercise was the opportunity to identify two main limits of our generation model. The first one can be illustrated with work-related trips in the morning (Fig. 2a): the volume of trips is correctly reproduced in 2010, but they are underestimated of about -20% for all the past horizons. The household surveys show that in 2001 a change occurred in the evolution of work-related trips in the morning (in black on Fig. 2a): after a slight increase between 1976 and 2001, this volume of trips declined between 2001 and 2010 (-0.5% per year). This sudden decrease can be largely attributed to the implementation of the 35-hour working week in 2001. This assumption is confirmed by the evolution of trips made for non-compulsory purposes: after a period of stability between 1976 and 2001 (less than +/-1% per year), there was a growth (+3% per year) between 2001 and 2010. There has been a shift between the two categories. Now, our generation model is based on the calibration situation (2010) and links the number of work-related trips during the morning peak hours to the employed population (in white on Fig. 2a). Then, the model does not integrate this important change in working time in 2001, which is why it does not reproduce the trend reversal. The estimation method also explains the slight increase in the number of reconstituted trips between 1983 and 1976: this is due to the rise of the employed population.

The second example is given by early childhood-related trips, which consist of young children and parents accompanying them. The volumes for the past horizons are overestimated, the gap widening over time (Fig. 2b). This is due to a change in parents' mobility that the model does not reproduce. Indeed, the household surveys (in black on Fig. 2b) show that this kind of trips have been steadily increasing since 1976 (just over +2% per year). A comparison with the volume of children under 11 years of age (in white on Fig. 2b) shows that this part of the population is far from following the same progression. Then, the observed dynamic is probably related to the evolution of lifestyles, and particularly to women's work, which has grown considerably since the early 1970s: half of women between 25 and 59 years of age used to work at that time, whereas in 2006 about 75% of them had a job (Afsa Essafi & Buffeteau, 2006). Since our model links the volume of early childhood-related trips during the morning peak hours to the population of children under 11 years of age, it does not recreate the impact of more working women, and therefore the evolution of this category of trips either.

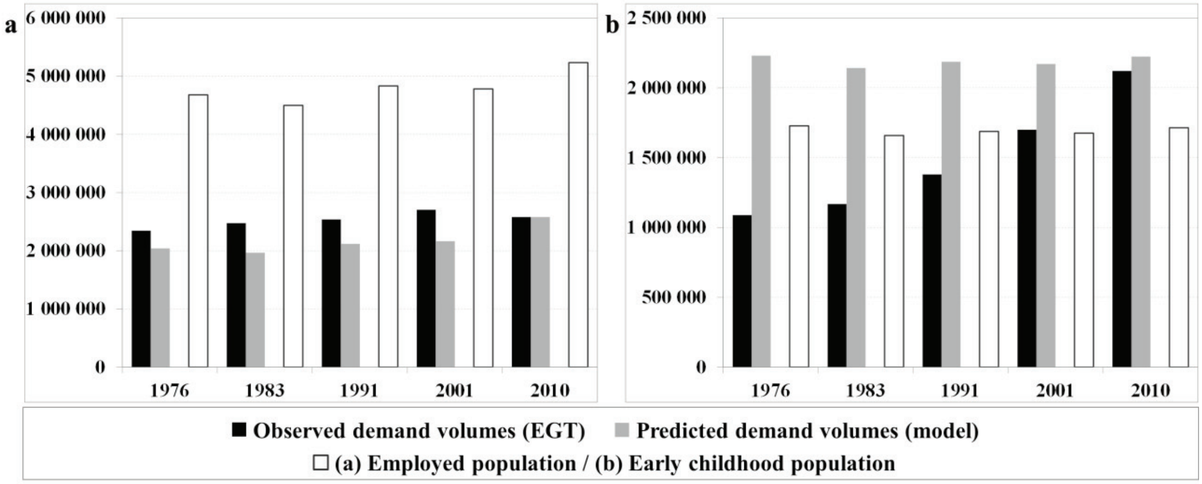

Fig. 2: Comparison of the observed number of trips and the predicted ones for work (a) and early childhood (b) purposes

3.2. Distribution

Figure 3 offers a comparison between the OD matrices reconstituted with the model, and the ones from the household surveys. Regarding the year 2010, which corresponds to the model calibration, the structure of the trips is correctly reproduced by the model: less than +/- 10% differences and the bigger differences correspond to the smaller volumes. For instance, Paris → Inner Suburbs represents less than 3% of the total.

Concerning 2001, the results are satisfactory too: the biggest volumes (the diagonal and the sums) are the ones with less discrepancy. This way, the reconstituted matrix structure is very close to the survey one (less than 1.5 points of difference on each O/D couple). The link Inner Suburbs → Paris is the less well reconstituted: it is due to a decrease on this link (-1.1% per year) between 2001 and 2010, which is not reproduced by the model, and this underestimation remains for all the past horizons. This decrease is mainly linked with the reduction of work-related trips in the morning.

In 1991, the estimated matrix structure is closed to the observed one (less than 2 points of difference on each O/D couples). The volumes are also globally correct. The overestimation of the volumes on the diagonal is mostly due to the early childhood-related and the leisure-related trips.

2010	Paris	IS	OS	Total
Paris	-1%	+10%	+5%	+1%
Inner Suburbs	-6%	+6%	-1%	+4%
Outer Suburbs	-4%	+7%	+1%	+1%
Total	-3%	+6%	+1%	+2%

2001	Paris	IS	OS	Total
Paris	+2%	-2%	-11%	+1%
Inner Suburbs	**-24%**	+6%	-12%	-0%
Outer Suburbs	-5%	-13%	+5%	+2%
Total	-6%	+3%	+3%	+1%

1991	Paris	IS	OS	Total
Paris	+13%	-5%	-10%	+9%
Inner Suburbs	**-21%**	+15%	-17%	+6%
Outer Suburbs	-10%	-14%	+14%	+9%
Total	-0%	+9%	+12%	+8%

1983	Paris	IS	OS	Total
Paris	+4%	+9%	+3%	+4%
Inner Suburbs	-18%	**+23%**	+3%	+13%
Outer Suburbs	-19%	+1%	**+23%**	+16%
Total	-6%	+19%	**+22%**	+13%

1976	Paris	IS	OS	Total
Paris	+7%	**+27%**	**+59%**	+11%
Inner Suburbs	-11%	**+37%**	**+44%**	**+27%**
Outer Suburbs	-13%	+11%	**+32%**	**+25%**
Total	-0%	**+34%**	**+33%**	**+23%**

Fig. 3: Comparison of the predicted OD matrices with the observed ones

Between 1983 and 1991, the number of trips to the suburbs increased sharply (+2% per year on average, and up to +4% per year on some routes). This is explained by urban sprawl and some economic activities movements from Paris towards the suburbs between 1976 and 2010. Indeed, according to the 1976 household survey, almost 80% of Parisian used to stay inside Paris to work, whereas in the 2010 survey, only 65% of them have a job in Paris and the others go to the suburbs. In addition, in 1976 there were 60% of work-related trips to the suburbs, and in 2010 they are 70%.

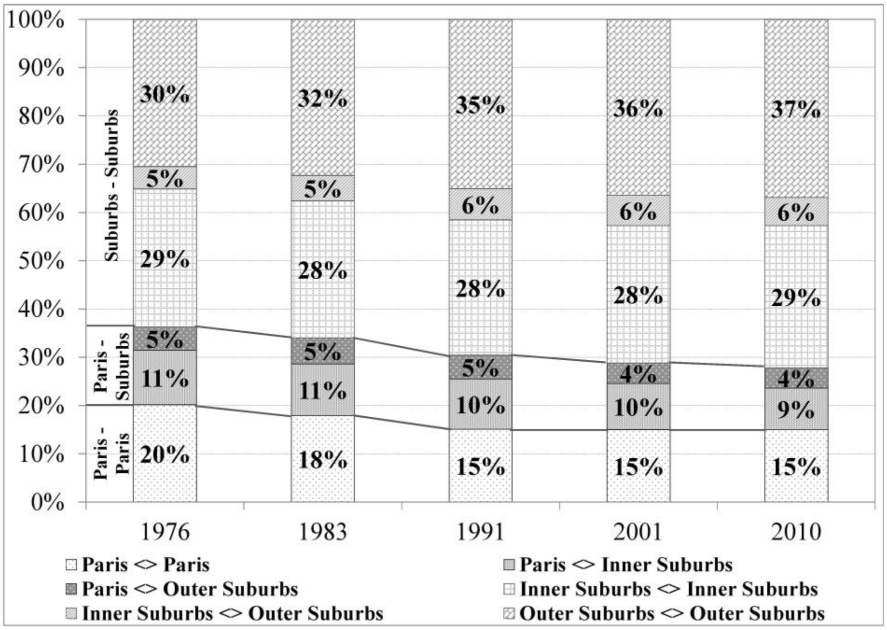

Fig. 4: Evolution of the geographic distribution of the demand (Sources: household travel surveys).

Fig. 4 highlights the dominance and the growth of suburb-to-suburb trips. This progression can be observed both in volume (+7 million of trips between 1976 and 2010) and in structure (almost +10 points since 1976) of trips

(Simeon, 2014; Observatoire de la mobilité en Ile-de-France). The distribution model does not reproduce these changes on the matrix structure; that is why the corresponding volumes are overestimated in 1983. This evolution in trips pattern also explains why in the 1976 matrix, suburbs-related trips are overestimated, whereas radial flows from the suburbs to Paris are underestimated. It can be notice that, globally, the average of differences between the surveys and the models results is going wider over time.

3.3. Mode choice

The first modelling results showed a great inertia in the modal shares distribution and did not reproduce the observed evolutions on the PT modal share on the morning. The PT modal share, compared to the car one, suddenly increased between 2001 and 2010 (+3 points), marking the end of the car use progression (Fig. 5). This trend reversal was particularly perceptible in Paris and the inner suburbs. Because the model does not reproduce this evolution, it systematically overestimates the PT modal share for the past horizons. And the overestimation is as great as the modal share increase was important between 2001 and 2010 (for instance, on the links Outer Suburbs → Paris and Inner Suburbs → Paris).

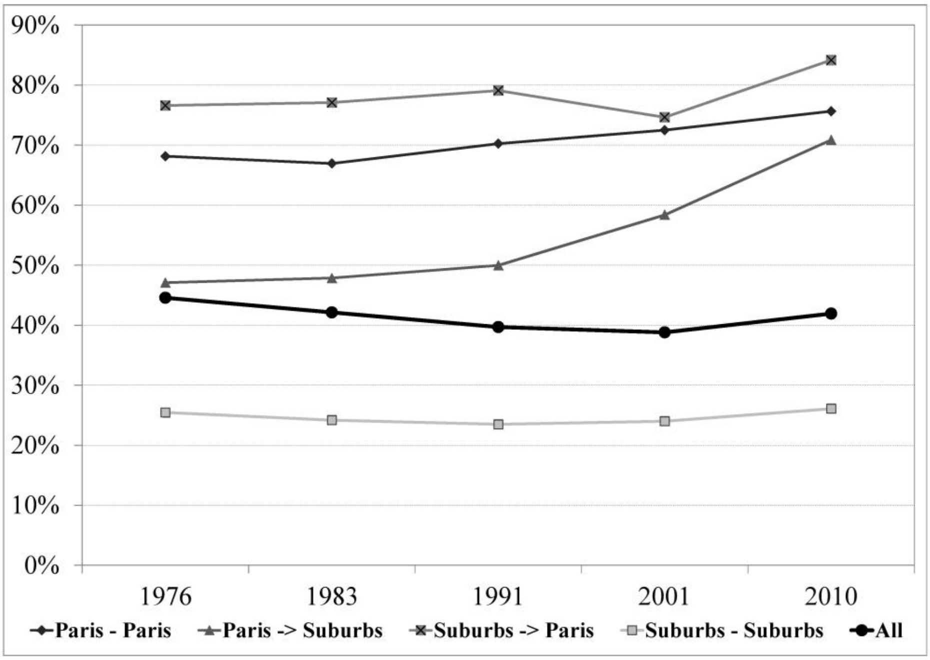

Fig. 5: Evolution of the PT mode share during morning peak hours by type of link (Sources: household travel surveys)

The reason why the model cannot reproduce the PT modal share progression between 2001 and 2010 is that the PT network did not change that much between 1991 and 2010. Indeed, this change in behavior was largely motivated by a policy, conducted in Paris since 2001, aiming at reducing car usage. Then, the few PT developments are not sufficient for the model to estimate the increase of the PT mode share. This is why we had to make some adjustments in order to facilitate the use of the car:

- Increase of the car ownership rate: the past population censuses show that car ownership tends to decrease in the urban area heart. This parameter has been corrected for each city using data from censuses in 1990 and 1999.
- Specification of parking conditions, particularly in the inner suburbs: parking conditions have hardened in recent years, especially in densely populated areas. However, we had no data available to quantify this evolution. Thus,

in order to estimate a situation with more flexible conditions, parking constraints were changed by approaching low values observed today in each department. This lever has a lot of influence on the car modal share.

- Improvement of global driving conditions: in Ile-de-France, it is difficult to conclude on an upward or downward trend regarding travel speeds by car. However, it was found that this parameter had relatively little influence on modal share levels, because the model is not very sensitive to it. Thus, for 2001, it was decided to increase the speeds of +10% on major routes, this value represents the upper range of observed variations of speed.

Fig. 6 and Fig. 7 compare the modal shares according to the household surveys (in white), with the estimated ones before (in grey) an after (in black) adjustments. Car-related modifications clearly improved the modal shares.

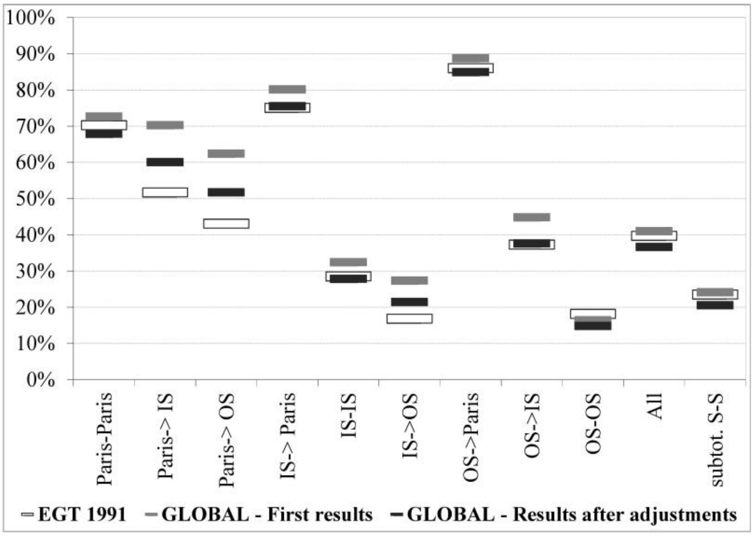

Fig. 6: Comparison of the observed mode share PT / (Car+PT) in 1991 and the predicted ones

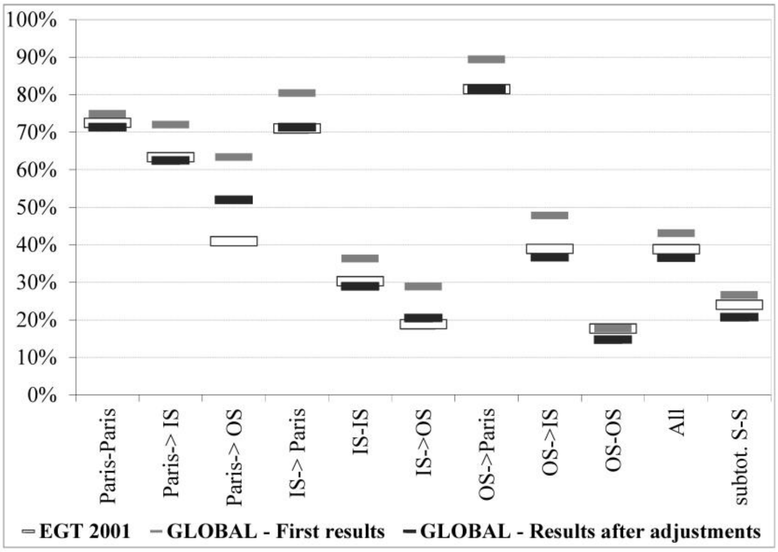

Fig. 7: Comparison of the observed mode share PT / (Car+PT) in 2001 and the predicted ones

3.4. Public transport assignment

The last part of this work was to compare the counts on the RATP railway lines according to the modelling results and the traffic statistics (as shown on Fig. 8 and Fig. 9). This exercise was only carried out for 2001. To do so, the coefficients of generation were adjusted to approximate, for each group, the trips volumes identified in the household survey. We compared two indicators:

- The trips number on each RATP line;
- The lines' maximum load, which determines the offer on the line.

When comparing traffic forecasts made during the upstream phase (about ten years before, which is our case in this experiment) and traffic observed after the project's commissioning, it is common to be within a margin of error of +/-20%. This range reflects the uncertainty related to the modelling tool, but also, and especially, the margins of uncertainty related to the study hypotheses (as the configuration and the project itself, the definition of other projects on stream by the horizon studied, urban developments, etc.).

Fig. 8 illustrates the differences between the number of trips reproduced by the model and the traffic counts.

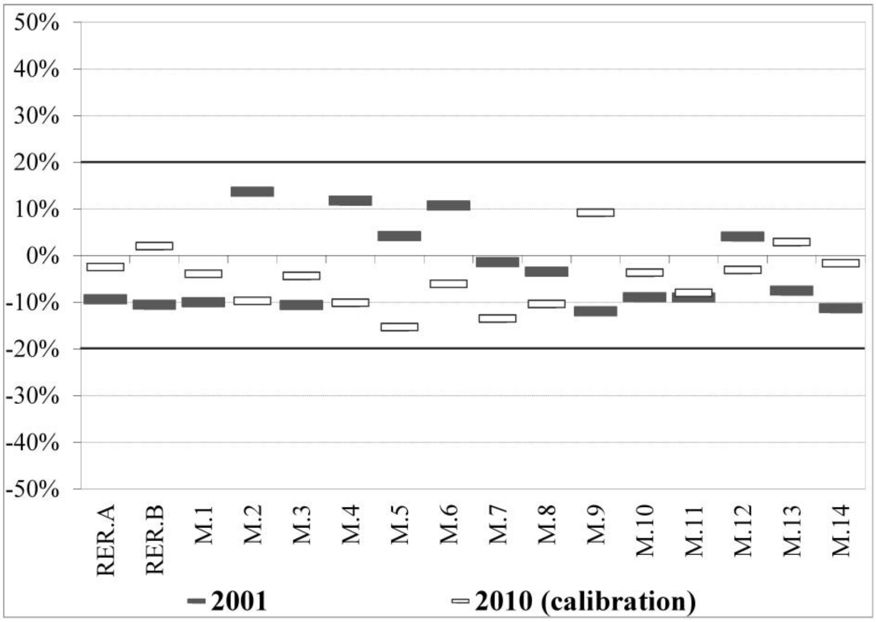

Fig. 8: Analysis of modelling results (comparison with 2001 traffic counts) regarding the number of trips per line

The reproduction of the trips number on the RATP lines in the morning is satisfactory: less than +/-15% differences between the estimates and the counts for all the lines. Overall, the number of trips is slightly underestimated (-4%), which is connected to the PT modal share underestimation (-2 points in comparison with the household survey) observed in the previous section.

The distribution step showed that radial flows were underestimated, especially between the inner suburbs and Paris. The detailed analysis of the use of the lines shows that the number of travelers using the lines from the suburbs is too weak in the model. This explains the underestimation of the trips number on the two urban railways (RER A and RER B), and extended suburban metro (in particular, line 1, line 3, line 9 and line 11).

In addition, the global calibration of the model across Ile-de-France is the result of a better compromise. Then, some lines in 2010 show deviations from the counts, which can influence the traffic forecasts. Thus, the lines with the bigger discrepancies with the counts (lines 2, 4 and 9), are also among the less well recovered at the calibration horizon. However, the PT traffic assignment results can be improved by a local calibration. In a transportation project context, this kind of difficulty is then overcome since a specific calibration is conducted on the studied line, using more local levers.

Finally, non-modelled parameters, as line reliability and comfort on board, can influence the forecast results. Indeed, line 2 is the one with the largest difference with the counts (trips number overestimated by +15%). It is also the line where attendance has increased the most between 2001 and 2010 (almost +20%), whereas the line was not extended. However, between 2005 and 2009, it underwent several modernization plans; in particular, the rolling stock was changed, which made the line more attractive. The model does not reconstitute this significant increase in attendance, which leads to an overestimation of the overall use of the line.

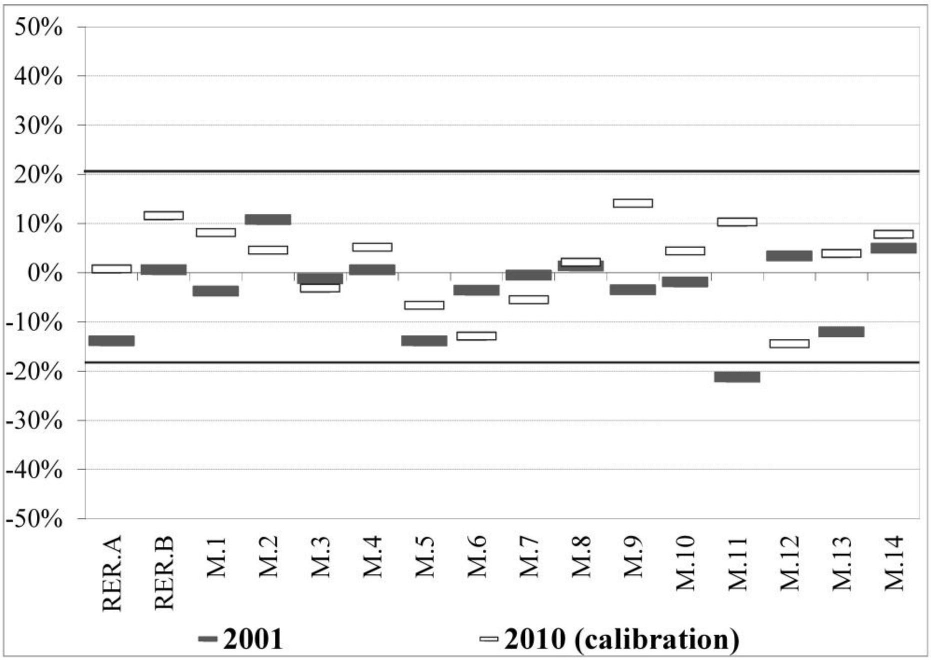

Fig. 9: Analysis of modelling results (comparison with 2001 traffic counts) regarding the maximum load per line

Regarding the loads estimation (Fig. 9), results are satisfactory: all loads are estimated with less than +/-20% difference, except on line 11, which is globally under-loaded in the model (trips number underestimated by -9% and maximum load by -21%.

4. Conclusion and future work

This exercise brought us some interesting and enlightening results. However, we were first confronted to the difficulties to compare modeling results with past surveys data. Indeed, data collection methods and survey methodology are continually improving. This can make it difficult to analyze historical data series, since data from different horizons are not always comparable.

Generation, estimated on current behavior, model does not take into account changes in travel practices. Thus, trend breaks are not modelled, because they are unpredictable. Overcoming this problem requires an analysis based on expert judgment. It is recommended to model several scenarios: depending on the context, the modeler may consider a possible break in trend. Moreover, if an evolution trend is noticed in past data series, it is possible to apply a dynamic change to the generation coefficients. To do so, the modeler will have to seek to understand the future of a dynamic seen in the past (continuation or slowdown).

The distribution model appears to be quite inert and does not take into account significant changes in travel patterns (related, for instance, to infrastructure developments or major urban projects). Indeed, the Fratar algorithm has its limits when some urban sectors are strongly growing. However, a gravity model, which has not been used in the current exercise, is integrated to GLOBAL and could partially solve the problem. This step in the analysis enables us to measure the importance of taking into account any significant changes in the matrix. This is why we plan to launch an internal work in order to improve our model of transport demand.

The modal choice step showed that, alone, the PT network does not lead to significant changes in the modal shares distribution. We identify two effective levers to change the car use, namely the parking conditions and car ownership. However, these elements are very difficult to plan, so they are generally not used for traffic forecasts. In the current context of changes in trend regarding the car use, it is recommended that the modeler keeps this limitation in mind. In addition, we plan to work on this topic to better understand parking policies impact, and to analyze the recent researches on trends in car ownership. However, studies on the Great Paris PT network showed that in the case of major changes in the PT offer, the model improves the PT modal share.

Traffic assignment appears to be the synthesis of all the effects identified above. To achieve it, we had to make simple corrections on observed biases. We noted that, at an aggregated level, the model was working well on lines that were changed between 2001 and 2010: it is the case of lines 13 and 14, which both have been extended. The importance of non-modelled parameters can be reminded. We are working on a new assignment algorithm which will take into account passengers' density on board.

This work was an interesting opportunity to question the ability of models to predict the future. The analysis of the differences between our estimates and survey results clearly shows the limits of the mobility behavior stability hypothesis (although, as we previously mentioned, the modeler has little flexibility on this point during the conception of the model). This assumption gives the model a high inertia, which is important to keep in mind when analyzing and interpreting modelling results. This exercise is then a good illustration of the uncertainties associated with the modeling results. These uncertainties come mainly from two main sources: on the one hand input data may be incomplete and therefore require assumptions, and on the other hand, the methodology simplifications are necessary to guarantee a practical tool, quite easy to understand and to use. However, the discrepancies between predicted demand flows and observed ones stay within an acceptable range (+/-20%).

Finally, we confirmed the relevance of the model and its results: we showed that all differences are mainly explained by "external" factors. Thus, the previous analysis attests to the usefulness of the model, since the anticipation of changes in behavior and urban policies are outside its fields. The exercise allowed us to better identify, objectify, and quantify the model limitations, and then to define work areas to improve it.

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